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Technological Innovation, Firm Performance, and Institutional Context: A Meta-Analysis

Abstract

Technological innovation, a complex and multidimensional construct, refers to innovations associated with an organization's operations, such as the introduction of new/improved products or processes. Scholars and practitioners recognize the importance of technological innovation in a firm's ability to obtain a sustainable competitive advantage. However, the empirical findings on the overarching relationship between technological innovation and firm performance remain inconclusive. Thus, in this study, we attempt to reconcile the mixed empirical results on the relationship by employing a multivariate meta-analytic methodology. We find that technological innovation has a significant and positive impact on a firm's performance. Further, we find empirical support for the moderating influence of cross-cultural and institutional differences on the relationship. We observed a better performance outcome for innovation occurring in nations with a lower propensity to avoid uncertainty and collectivistic attitudes. In contrast, performance suffers when technological innovation occurs in nations that have stronger patent protection.

Keywords Meta-analysis, Technological Innovation, Firm Performance, Institution-based View, National Culture.

1 Introduction

Scholars argue that a firm's technological innovation initiatives are critical for their success and growth [1]. Even during the 2008 financial crisis, many US companies continued to invest in research and development (R&D) while cutting costs in other areas [2]. In today's competitive market, startup can quickly replace incumbent firms that fail to stay ahead of the innovation curve. In the presence of globalization and technological advancements, firms from emerging markets are steadily gaining dominance over their developed-country counterparts by merely innovating new products and services [3]. Thus, firms need to continuously innovate to ensure competitive advantage and maintain their position in the market [4]. However, some scholars argue against the performance benefits of technological innovation due to the (a) associated high investment costs, (b) uncertainty of returns, (c) long delays in reaping returns, (d) difficulty of effectively measuring returns, and (e) perceived risk of failure by management, among others [5, 6].

Further, the inadequacy of existing technological innovation measures complicates the credibility of empirical findings on technological innovation and firm performance [7]. As technological innovation does not occur in a vacuum, environmental conditions (both internal and external) exacerbate the problem [7, 8]. Prior literature examined how the implementation of technological innovation is influenced by factors such as the country of operation and its culture [9], environmental turbulence or uncertainty [10], the industrial network of operation [11], supplier involvement [10, 12], organizational size [11, 13], and organizational structure and processes [14]. The evaluation of specific contextual factors, mainly cross-country differences, can get overwhelming for traditional style studies due to methodological and sample size limitations. Thus, for the scholarly advancement and informing practice, a quantitative aggregation of all prior innovation-related studies using meta-analysis methodology is essential. It allows us to examine

the impact of contextual factors that would otherwise be difficult to assess. Specifically, in this paper, we examine the technological innovation and performance link using the institutional and the cultural environment of a nation within which a firm operates. As our focus is on technological innovation, from here on, we use ‘innovation’ and ‘technological innovation’ interchangeably.

As mentioned earlier, studies suggest that a firm’s environment (both internal and external) can enable or inhibit the performance benefits from innovation activities [15-17]. First, the institution-based view informs that firms enjoy more significant performance benefits to innovation activities in nations with stronger institutional environments [17]. In the literature, two characteristics of a strong institutional environment are (a) the level of financial development and market regulation, and (b) the strength of intellectual property rights [18-20]. Since technological innovation is a high-cost activity, firms operating in a financially developed and regulated nation perform better. Additionally, firms that operate in nations with a stronger protection for intellectual property can better monopolize financial returns on innovative products. Second, both practitioners and scholars have emphasized the importance of cultural elements in influencing innovation [9, 21]. In the context of innovation, the two most commonly studied cultural elements are ‘degree of individualism’ and ‘uncertainty avoidance’ [22], and empirical results have been shown to vary across these two dimensions [23]. Consequently, using multivariate meta-analytical techniques specifically designed to capture and assess such conflicting relationships, this paper focuses on providing a resolution to this ongoing debate and providing contextual insights about performance sensitivity to innovation efforts. Therefore, in the paper, we assess:

1. Do technological innovations enhance a firm’s performance?

2. Does the relationship between technological innovation and firm performance differ across nations with varying institutional environments in terms of ‘extent of capital market regulation’ and ‘strength of intellectual property rights’?
3. Does the relationship between technological innovation and firm performance differ across nations with varying cultural environments in terms of ‘uncertainty avoidance’ and ‘degree of individualism’?

The rest of the paper is structured as follows. Next, we provide a brief overview of the relevant literature and develop theoretical arguments for study hypotheses. Then, we describe the meta-analytic methodology, and the procedure for selecting and coding included studies. Immediately after, we report and discuss the results of statistical analysis. We conclude with a discussion of study limitations and some guidance for future research.

2 Literature Review and Hypotheses Development

2.1 Technological Innovation

Prior research on innovation has categorized it in several ways [24]. For example, a popular typology to date is the distinction between “*technological*” and “*administrative*” type of innovation [25]. Technological innovations are defined as “*the conversion of ideas and knowledge into new and commercially successful products and services*” and they “*occur in the operating component*” of both manufacturing as well as service firms, and affect “*the equipment and methods of operations used to transform raw materials into products or services*” [1, 25]. Technological innovation is a multi-faceted construct, and the goal to capture it appropriately and adequately remains an open research area [26]. Thus far, scholars have employed numerous measures, comprising both perceptual [14] and objective types. The objective measures include, but are not limited to, R&D expenditures [12, 27], R&D intensity [28], patent counts [29, 30], patent citations

[30], new product introductions [31], product radicalness [32], innovation-related announcements [33], and innovation awards [7]. All these existing measures offer their own set of contributions and drawbacks [7].

R&D spending is the most frequently used measure of technological innovation in empirical research. As a financial measure, it allows comparison of firms based on spending levels as a percentage of sales and suggests that firms spending more also innovate more. However, R&D fails to capture a firm's internal capabilities to innovate. It incorrectly assumes that firms are homogenous, with any two firms performing identically at a given R&D level. Recent research suggests that firms, in fact, differ in their abilities to innovate [34]. Innovation is not solely based on high amounts of R&D investment but also on the working environment within a firm, for example, whether employees pursue risky ideas with the potential of a breakthrough [5]. In brief, innovation has multiple dimensions, and no single measure can capture it in totality, at least not as yet [7]. Given such a setting, a meta-analysis that incorporates various operationalizations of technological innovation can enrich our understanding of the relationship while controlling for the differences.

2.2 Impact of Technological Innovation on Firm Performance

Technological innovation and firm performance relationship have been extensively investigated across disciplines, but results are mixed and inconclusive [28, 32]. Some scholars have argued for a negative relationship between it and firm performance because of the associated sky-high investment costs, uncertainty of returns from those investments, and long delays associated with those investment returns [35, 36]. For example, Durand et al. [29] reported that a firm's financial performance in the biotechnology sector is negatively affected by its patent activity. Similarly, Terwiesch and Loch [37] concluded a negative to no impact of innovation intensity on a firm's

profitability. Further, Zhang et al. [7] argued that the market only rewards ‘commercially-successful’ innovations while ignoring efforts in innovation like patenting. That may exacerbate the challenge of accurately measuring a firm’s financial returns from innovation investments given the increasing speed of innovation diffusion across global markets and the existence of diverse patterns of consumer adoption across products and countries [6, 35, 38].

Studies suggesting a positive relationship between the two focal variables include a seminal meta-analysis by Capon et al. [39]. The paper reported that R&D-intensive firms achieve better financial performance. Chaney and Devinney [40] similarly found positive market returns from innovation announcements. A survey-based study by Oke [32] also concluded innovation to be positively related to firm performance. Finally, Zhang et al. [7] reported innovation-award winning firms to be financially more successful.

A different tributary of research in this area has sought to examine reasons for the inconclusive nature of technological innovation and firm performance relationship. For example, some researchers assessed the influence of contextual factors on innovation and firm performance relationship. Jansen et al. [14] found that exploratory innovation had a positive impact on a firm’s financial performance, while exploitative innovation had a negative impact if the operating environment was dynamic. Thornhill [41] concluded that innovation positively impacts performance under the effect of industry dynamism.

Some scholars have attributed the contradictory findings to the lack of an all-encompassing and generalizable measure of technological innovation. Heeley et al. [42] studied the effect of R&D and patenting on a firm’s performance and found opposing results. They posit that R&D investment as an input to the innovation process is a marker of the firm’s innovation, while patenting reflects a firm’s innovation output. They empirically showed that higher R&D intensity

led to an increase in stock returns, but patent count had no effect on stock returns. Given the drawbacks of the existing measures, Zhang et al. [7] deployed innovation awards as a new measure of innovation. They argue that winning an innovation award measures the overall effectiveness of that innovation, which goes beyond merely introducing an innovative product/process, thereby providing a more accurate picture of its effect on firm profitability.

To summarize, the extant literature has explored various pathways to explain the conflicting nature of technological innovation and performance relationship, but given the associated complexity and richness of the debate, a generalizable conclusion is yet to be found. Our literature review suggests that the overall findings nevertheless lean heavily towards a positive relationship between the two variables. Accurately assessing the effects of technological innovation on firm performance using meta-analysis can aid in empirically proving whether markets respond favorably to innovation, which in turn can motivate firms to invest in it. Thus, we hypothesize:

Hypothesis 1. Technological innovations of a firm are positively related to its performance.

2.3 Impact of Country-Level Moderators

2.3.1 Influence of Institutional Environment

According to the institution-based view (IBV), a country's institutional environment influences the outcomes of a firm's initiatives[43]. The term 'institutional environment' of a nation represents the rules and regulations created by different institutional forces like political, legal, economic, and social systems. Ignoring the institutional environment may prevent us from getting a deeper understanding of the drivers of firm performance in developed [15] and developing countries [44]. Heugens et al. [17], in their meta-analytic study covering 11 Asian countries and 65 research papers, concluded that jurisdictional institutional factors had a significant role in determining firm

performance. Research in various disciplines utilizes IBV, a leading strategic perspective, to explain firm-level heterogeneity [16, 45-47]. A study by Li et al. [16] examined the role of offshore OEM cooperation on local Chinese suppliers under the influence of ill-developed formal institutions that are found in China. Another recent study by Wang et al. [47] examined the role of the institutional environment on buyer-supplier relationships in emerging markets.

In this paper, we argue that the institutional environment of the nation in which the firm operates can explain the heterogeneity in the strength of the focal relationship. In their (2009) report, UNESCO's Institute of Statistics (UIS) remarks that a weak institutional environment impedes innovation. While the institutional environment has many dimensions, we focus specifically on a) the level of financial development and b) the level of intellectual property protection in a given nation.

As funding requirements are higher for innovative firms, they tend to perform better in financially developed nations. An indicator of a nation's financial development is *capital market regulation*. Firms use the capital market to raise long-term funds. The availability of long-term funds enables a firm's innovation activities. An innovation project typically requires multiple stages over a considerable amount of time [48] during which the lending agencies re-visiting its creditworthiness. The government monitors and regulates the capital market to ensure its efficient functioning. The primary purpose of these regulations is to protect investors from fraudulent transactions. Scholars have examined the impact of capital market regulations on economic activity in a nation [49, 50]. Robust capital markets (characterized by the availability of financial credit) have positive impact a firm's innovation [49, 51]. Barbosa and Faria [49] used the availability of credit information (CII) as the proxy for capital market regulation. To conclude, well-regulated capital markets would allow reliable and timely access to credit. One way to

improve access to credit is by making a firm's creditworthiness information reliable and accessible. Hence, the availability of credit information will moderate the focal relationship, which leads to next hypothesis.

Hypothesis 2. *The stronger the capital market regulation in a nation, the stronger the relationship between technological innovation and firm performance.*

In addition to better access to capital, possessing rights of ownership (e.g., in the form of patents and trademarks) on the product/s of their innovative activities (referred to as the intellectual property) also enables firms to monopolize the returns on innovation [52]. The primary motivation for a firm's investment in innovation is to augment profits and maintain a competitive advantage. The financial benefits from an innovative product to a firm is contingent on its ability to monopolize the product sales in the target market while limiting imitation by competitors [53] [54]. In the current operating environment, innovating firms need to protect their inventions from domestic and global competition [55]. Governments have thus created a legal framework to protect the intellectual property of innovating firms with the objective of (a) incentivizing domestic firms to innovate and (b) attracting investment from multinational firms [20]. The strength of patent protection in a country is measured using Ginarte and Park's *patent protection index (PPI)* [52]. The index is composed of five dimensions: (1) extent of coverage of inventions that are patentable, (2) membership in international patent treaties, (3) duration of protection, (4) enforcement mechanisms, and (5) restrictions on patent rights [56]. Since patent protection enables innovating firms to prevent imitation of their innovations, monopolize the market, and maintain their competitive edge, we hypothesize:

Hypothesis 3. *The stronger the patent protection in a nation, the stronger the relationship between technological innovation and firm performance.*

2.3.2 Influence of Culture

The influence of national culture on firm performance is well-established in various disciplines [9, 57]. Cultural values and practices are engrained within citizens of a nation. The management practices of a firm reflect the country's cultural mindsets in which the firm is based. The majority of the work done on cross-cultural comparisons has adopted Hofstede's cultural framework [9, 58]. The framework has six dimensions of culture: power distance, uncertainty avoidance, individualism vs. collectivism, masculinity vs. femininity, long-term vs. short-term orientation, and indulgence vs. restraint [59]. He proposed that national culture defines and influences how a firm's management and employees adapt to new practices and ideas, how they solve problems, how they make decisions in uncertain business situations, whether they value teamwork over individual accomplishment and more; and in turn affects firm outcomes. A firm's innovation-related initiatives are not foreign to this influence either. Becheikh et al. [60], in their comprehensive review of empirical studies on innovation in the manufacturing sector, found a significant heterogeneity on the effects of culture on a firm's innovation-related outcomes. Hence, cross-cultural differences play a role in whether firms succeed with the introduction of innovations.

Two out of the six cultural dimensions that Hofstede proposed fit well in the context of technological innovation based on its inherent nature and the inclination of the extant empirical research. First, the dimension of Individualism vs. Collectivism (IDV) is widely utilized in firm-level research [57]. Empirical evidence on the impact of IDV on our focal relationship is at best inconclusive [23], which was further motivation to include IDV as a moderator since meta-analysis can help potentially reconcile the differences. The IDV captures the degree to which people emphasize individual merit and accomplishments. Higher the value on this dimension,

more individualistic is the nation's culture. The traditional view in terms of the impact of IDV propagates that since highly individualistic nations value autonomy, competition, and freedom, they tend to reap better financial benefits [58]. A more nuanced view asserts that individualistic countries tend to perform better in projects that warrant 'individual accountability and recognition' compared to projects that require 'teamwork' [61].

Findings from the second stream of research demonstrate the opposite. Power and his colleagues [9] assessed the influence of 'individualism vs. collectivism' on innovation-related investment outcomes in Western and Asian economies. They concluded that innovation-related investments led to better performance in collectivistic (Asian) countries than in individualistic (Western) countries. Rosenbusch et al. [23] also concluded that firms based in collectivistic cultures benefitted more from innovation because they work on projects collaboratively involving employees, customers, and suppliers. Moreover, they argue that since fewer firms strive for innovation in collectivistic cultures, those firms that indulge in true innovative behavior can benefit more from their efforts than firms based in cultures where the bulk of them pursues innovation. These empirical findings hold merit in case of some Asian economies. For example, South Korea scores relatively low on IDV, meaning the country has a more 'team-oriented' culture. However, it is one of the highest-ranking nations for R & D spending, innovative products, and services as well as boasts an excellent R & D infrastructure [62]. Japan is a similar story in that it is highly 'relationship' and 'people' focused but still manages to be a pioneer in manufacturing related innovative endeavors [63].

Technological endeavors today require collective brainstorming of ideas and teamwork in facing the associated and unprecedented challenges. A collectivistic/team-oriented culture promotes communication and cooperation among team members. Firms in individualistic nations

like the US are also starting to realize the value of bringing people from different areas of expertise to come up with new/improved products. Ideo, a global design firm based in California, US, responsible for the design of the Apple mouse, operates on the same principle and has enjoyed tremendous success thus far. To illustrate with another example, Yahoo revoked mobile work privileges, and Facebook got rid of individual cubicles in their office building [64]. Thus, building on the above arguments and real-life industry examples, we hypothesize that:

Hypothesis 4. *The lower the degree of individualism in a nation, the stronger the relationship between technological innovation and firm performance.*

Additionally, the Uncertainty Avoidance (UAI) dimension captures the overall degree of averseness of a country's citizens to uncertainty and ambiguity. Higher the value on this dimension, lower is the degree of discomfort of the nation's culture with uncertainty. The extent to which the citizens avoid unknown future situations can negatively influence the performance outcomes of innovation [62, 65]. Conversely, the acceptance of new ideas, and innovative products/processes, can positively influence performance outcomes of technological innovation [38]. For example, Becheikh et al. [60] found that cultures ranking low in UAI were overall more innovative. Given that innovation is the implementation of new and challenging ideas with uncertain outcomes, it is posited that firms would perform better if located in cultures that do not shy away from delving in innovative projects with unpredictable outcomes. Thus, we propose:

Hypothesis 5. *The lower the degree of uncertainty avoidance in a nation, the stronger the relationship between technological innovation and firm performance.*

Figure I displays the proposed model along with hypothesized relationships.

---Insert Figure I here---

3 Data and Methodology

We use a Meta-Analysis (MA) to summarize, interpret, and compare different empirical studies that examine the same construct(s) and relationship(s). We followed Lipsey and Wilson's [66] MA procedure, referred to as the LW procedure, for all the steps from study selection to analyzing coded data.

3.1 Study Selection

We established a sample frame, to assess the proposed model, by collecting empirical studies that theorize and measure the focal relationship. This effort included carefully examining Google scholar, web of science, EBSCO, and JSTOR databases, and filtering studies using search terms including but not limited to "performance", "innovation", "R&D expenditure", "patent", "new product introduction", "technological innovation", "product innovation", "process innovation", "innovation award", "innovation survey". We screened thirteen journals for relevant papers. In addition to Management Science (MS), Academy of Management Journal (AMJ), Strategic Management Journal (SMJ), Research Policy (RP), and Journal of Product Innovation Management (JPIM) that comprise the top five most-cited journals to publish innovation-related research [67], the journal list included Journal of Operations Management (JOM), Productions and Operations Management (POM), Decision Sciences (DS), International Journal of Operations and Production Management (IJOPM), International Journal of Production Economics (IJPE), Journal of Business Venturing (JBV), International Journal of Business (IJB), and Journal of Management Studies (JMS). Also, Zhang et al. [7] provide an excellent review of innovation literature, and added two more papers to the sample from it.

After accumulating the first set of studies, we examined each paper to ensure only those that analyzed the focal relationship is included. The shortlisted papers were empirical and included

all the information needed to conduct MA. Accordingly, we excluded conceptual papers, qualitative papers, case studies, and analytical-modeling papers. We also screened the reference lists of papers to search for any other potentially relevant papers not in our list. This process resulted in a final sample of 28 studies., which is consistent with other published MA studies [68-70]. We provide the list of studies in Appendix.

3.2 Coding Procedure

We carefully evaluated each study. Technological innovation and firm performance have been conceptualized and operationalized differently across research disciplines. Measures of performance gathered from the collected sample comprised of objective measures (e.g., market measures like Tobin's Q and market share; and accounting measures like ROA and ROS), and subjective measures (e.g., single-item or multi-item Likert-based survey data). Similarly, technological innovation measures are comprised of objective measures (secondary sources and/or economic data) and subjective measures (single-item or multi-item Likert-based). We included all measures of performance and technological innovation regardless of their type. The practice is consistent with published MA studies [46, 68, 71, 72]. We examined the operationalization of all variables (performance, innovation, and control variables, if any) in each of the 28 studies for coding purpose, and for any transformation where needed. There was significant heterogeneity among collected besides differences in operationalization of variables. For example, the majority of the studies examined the relationship in the manufacturing sector with cross-sectional data. Only two studies used inspected panel data. Table I reports descriptive statistics for the final sample.

---Insert Table I here---

To test for H1, effect sizes between all variables (dependent, independent, and control variables, if any); their significance test values (t-statistics, z-value, and/or p-value); and sample

sizes from each of the 28 studies were coded. The LW procedure uses a statistically standardized ‘effect size’. Correlation was used as the effect-size statistic [17, 46, 71]. If a study contained multiple measurements of the focal relationship(e.g. [42]), all measurements from that study were included because it ensures higher estimation accuracy [73]. Since MA focuses on both the direction and magnitude of the effects across studies and not on statistical significance, both significant and insignificant effect sizes from each paper in the study sample were included to reduce bias in outcomes. This approach is also consistent with previous MA studies [68, 70, 71, 74]. We use ‘effect size’ and ‘correlation’ interchangeably hereafter.

We included both bivariate correlations and partial correlations as effect sizes [46, 66, 75]. Partial correlation is an unbiased, scale-free, linear estimate of association that renders the capability to detect model misspecification and is the commonly used effect size. Using partial correlations makes it possible to include studies with missing effect-size data since it can be directly computed from the regression output. Not all studies embodied both types of correlations in the study sample. Therefore, to ensure inclusion of each study in the analysis, we aggregated the data from both types of correlations [76]. In total, we obtained 132 effect sizes from the 28 studies in the sample, out of which 87 were partial correlations, and 45 were bivariate correlations.

We transformed all effect sizes to a Fisher Z-transform [77] before being using in the analysis to control for skewness in the effect-size distribution. This transformation ensured that all effect-size values were now relatively closer to a normal distribution. Additionally, the effect sizes are weighted using an inverse variance weight, denoted by w [77]. The sample size (N) of each study was used to weight the effect size obtained from that study, so that studies using a larger dataset carry more weight than those using a smaller dataset.

In the study, we proposed four new moderating variables and extracted their data from independent sources to H2-H5. The first moderator called ‘*Credit Information Index (CII)*’ is a proxy for capital-market regulation to test H2. The second moderator called ‘*Patent Protection Index (PPI)*’ is a proxy for strength of patent protection in a nation to test H3. The third moderator called ‘*Individualism vs. Collectivism (IDV)*’ is used to test H4. The fourth moderator called ‘*Uncertainty Avoidance (UAI)*’ is used to test H5., We orthogonalized all four moderators before conducting MARA to control for multi-collinearity.

Next, it also needs to be determined if the heterogeneity in the effect-size distribution is influenced by the studies’ design and methodology [66]. Based on the varying methodological characteristics of the 28 studies, we created five methodological moderating variables. We used two dummy variables to capture if study used only manufacturing-industry data or only service-industry data, or data from both industries (10=manufacturing industry data, 01=service industry data). Additionally, we included dummy variables for: (1) use of cross-sectional data or panel data, (2) controlled for firm size or not, and (3) controlled for industry effects or not. Table II provides a description of moderating variables in the analysis.

---Insert Table II here---

4 Analysis and Results

We used the STATA macros provided by Lipsey and Wilson for the analysis [66] and used two different meta-analytic techniques. We applied the Hedges and Olkin-type MA technique (commonly referred to as HOMA) [77] to test H1. HOMA computes the MA mean effect-size for the focal relationship, its standard deviation, and the corresponding confidence interval. Since the effect-size distribution for the focal relationship is assumed to be heterogeneous, we selected the random-effects model instead of the fixed-effects model. The random-effects HOMA model

corrects for both sampling error and other variability sources [77]. Also, the random-effects model is (a) more conservative than fixed-effects model, and (b) favored over a fixed-effects model in current MA practices [17, 46, 78]. Both models produce comparable results if the effect-size distributions are homogenous.

We used MA Regression Analysis (referred to as MARA) [66] to test H2-H5. MARA uses a weighted least-squares (WLS) regression model in which the dependent variable is the observed effect size for the focal relationship. MARA helps to fill in the gap on the causes of heterogeneity in the effect-size distribution by testing for two types of moderating effects: (a) methodological artifacts that cause the observed effect size to differ from the actual effect size, and (b) new/external moderating variables that were not part of any of the studies in the study sample. We included both the methodological artifacts and external moderators (CII, PPI, IDV, and UAI) to conduct MARA. We used the mixed-effects model to conduct MARA as it offers a lower Type-1 error rate and more conservative results [75].

H1 Results: Results reported in Table III indicate a positive and significant relationship between technological innovation and firm performance supporting H1

---Insert Table III here---

The mean of the relationship is 0.1 and is statistically significant with a p-value < 0.001; also, the 95% confidence interval does not include zero. The effect size is in the small-to-medium range [79], thus implying that technological innovation tends to positively but moderately influence firm performance confirming H1. We used the Cochran's [80] Q test of homogeneity and calculated the I^2 index to test for heterogeneity. The Q-test value is 2985.1 and is statistically significant with a p-value < 0.001. The I^2 index measures the degree of homogeneity, and a value > 0.75 indicates a high level of heterogeneity. The value of I^2 implies that the effect-size

distribution is substantially heterogeneous. Therefore, it is worthwhile to examine next how much of this observed heterogeneity is due to moderators.

H2-H5 Results: MARA was run to test H2-H5 with two different regression models, as shown in Table IV.

---Insert Table IV here---

Model 1 includes only the methodological variables. Model 2 represents the full model that includes both sets of variables described in Table II. Three statistics indicate the model fit: (1) the R^2 value, (2) the Q_{model} value, which represents the variance explained by the regression model, and (3) the Q_{residual} value, which represents the variance left unexplained by the model.

As per Table IV, the R^2 value increased from Model 1 (0.05) to Model 2 (0.14). Both models fit the data reasonably well, and the fit improves when moving from one model to the next. The Q_{model} value increased from Model 1 ($Q=10.75$; $p\text{-value}<0.05$) to Model 2 ($Q=29.32$; $p\text{-value}<0.001$). This implies that the full model (Model 2) captures the heterogeneity well. The Q_{residual} value decreased from Model 1 ($Q=193.66$; $p\text{-value}<0.001$) to Model 2 ($Q=174.31$; $p\text{-value}<0.01$) but remains significant. This implies that even though Model 2 fits reasonably well, the included moderators do not ‘fully’ capture the heterogeneity in the effect-size distribution. Hence, additional moderators need to be tested to account for the leftover heterogeneity.

Further examination of the MARA results in Table IV reveals that only three out of four moderators: PPI, IDV, and UAI are statistically significant. First, in looking into the moderating role of a capital market regulatory-type institutional context, results show that CII does not drive the focal relationship ($p>0.1$). Furthermore, CII has a negative moderating effect, contrary to what we hypothesized. Hence, H2 is not supported. This result was counter-intuitive as numerous studies have shown a correlation between financial development of a nation and firm performance

for the simple reason that firms need ‘access to capital’ [81]. This correlation is even more pertinent to innovative firms since innovation necessitates high investment costs. A possible explanation for the counter-intuitive result is that availability of credit information may not be the only factor capturing a firm’s timely access to capital. Availability and accessibility of borrower firms’ creditworthiness may still prompt a lender to deny the loan for various reasons. First, studies have shown that innovation-related investments are treated differently than regular investments because of the associated risks and unpredictable returns [5]. Second, most of the innovation investment is spent on intellectual capital (which is tacit) and intangible assets. This exacerbates the perceived riskiness and uncertainty of returns from such investment [5]. Recent literature suggests that access to credit is different for innovative firms vs. those of non-innovative firms [5, 82]. This is further complicated by whether the firm is a startup or an incumbent [82, 83]. Another possible explanation as to why the results here do not reconcile with extant research is omitted-variable bias. The results may reflect the omission of firm-level characteristics from the model like firm growth over time and firm assets, both of which can influence a lender’s decision to extend credit. In brief, the intrinsic nature of innovation, coupled with past firm innovation-related outcomes, might take precedence over the availability of credit information when it comes to lending decisions. Furthermore, the direction of the relationship is potentially being influenced by these omitted variables.

For H3, results indicate that the strength of patent protection (PPI) does in fact significantly moderate ($p\text{-value}=0.054$) the focal relationship, however not as hypothesized. Hence, H3 is only partially supported. This result runs contrary to the underlying assumption that incentives drive firm actions as well as what numerous previous studies have shown that PPI has a positive impact on innovation [20, 55, 84]. A possible explanation is that even though patenting provides

ownership over an invention, it publicizes a firm's internal intellectual capital. A study by Cohen et al. [85] discussed how competitors could work around the patent until its expiry, after which they can use the patent. This behavior discourages the innovating firm to patent their inventions. Second, Pisano [19] has argued that the impact of patent protection on the '*rate and direction*' of innovation and its outcomes is more complicated than what has been hypothesized thus far. Additionally, the choice to patent is dependent on the '*appropriability regime*' in which the firm operates. The appropriability regime in a nation is a combination of the strength of patent protection and the ease of imitability. Firms may not choose to patent their inventions if imitation is not a concern. Also, given that the primary motivation is to maximize its financial returns from an innovative product, firms today are following an alternate strategy of intentionally sharing their proprietary knowledge as long as the receiver does not appropriate it. Additionally, Lerner [84], also found strengthening the patent protection framework to impact innovation negatively. Hence, in the current age of technological advancements, the legal framework of patent protection is perhaps becoming more of a deterrent when firms are moving away from patenting their inventions.

In terms of the moderating role of national culture, both IDV and UAI negatively moderate the influence of technological innovation on firm performance. Hence, both H4 and H5 are fully supported. Results for H4 imply that firms based in highly individualistic cultures (or higher value of IDV) tend to experience lower performance outcomes from technological innovation. This result indicates that fostering collaboration and communication among employee groups and giving precedence to team-level success instead of individual freedom and accomplishment can promote better innovation-related outcomes. Similarly, firms based in nations having a higher value of UAI tend to experience lower performance outcomes with technological innovations. In

other words, firms whose employees do not pull back from uncertain and ambiguous circumstances can gain better innovation-related outcomes.

As observed in Table IV, none of the methodological variables achieved significance. Neither the temporal design of the study nor controlling for firm size or industry-level effects affected the focal relationship.

5 Robustness Test

We separated objective and subjective measures of technological innovation to perform separate HOMA for each category. This helped us assess if the overall results were independent of the operationalization of technological innovation. Results shown in Table V indicate that even though the direction of the focal relationship remains unaffected by the type of measure used, the strength of the focal relationship gets affected.

---Insert Table V here---

The focal relationship is positive and statistically significant ($p\text{-value} < 0.001$) for both types of innovation measures. However, the mean for the subjective-measure category is 0.195, while for the objective-measure category is 0.056. This implies that one would observe a more substantial influence of technological innovation on firm performance when subjective measures were employed, relative to when objective measures were employed. Summarizing, even though a modestly positive relationship is indicated between the focal variables, its magnitude varies and is driven by how technological innovation is operationalized (subjective vs. objective).

6 Conclusion and Implications

Zhang et al., in their 2012 [7] study, noted that the link between innovation and performance was “weak and inconsistent”. They attributed the inconclusive nature of the relationship to (a)

inadequacy of the existing innovation measures, and (b) lack of knowledge and understanding of the factors on which the innovation-performance link might be contingent. Use of MA afforded high statistical power in quantitatively compiling these mixed research findings. First, the relationship between technological innovation and firm performance is statistically significant and modestly positive. Second, these results further indicate that the sources of variability in the strength of the focal relationship stem not only from the different ways of measuring technological innovation but also from the contextual factors at play.

We introduced four new moderating variables (CII, PPI, IDV, and UAI) to account for the said variability. We find that the focal relationship is contingent on the institutional effect of the strength of patent protection in a nation. The direction of the result was, however, contrary to the hypothesis. Increasing the strength of patent protection tends to dampen the performance outcomes of technological innovation. This counter-intuitive result indicates that robust patent protection frameworks might, in fact, prove to be a deterrent to the firm seeking to maximize profits, especially in situations where the innovative product is either not vulnerable to imitation and intentional sharing of the intellectual property holds the potential to enhance financial returns.

Both IDV and UAI significantly influence the focal relationship when examining the impact of cross-cultural differences on the performance sensitivity to technological innovation. The suggested cultural environment for the focal relationship is low levels of individualism and low levels of uncertainty avoidance. Consider the example of the US that ranks low on UAI dimension and is number one in the Global Entrepreneurship Rankings Index (2017). Traditionally, the work culture in the US has supported autonomy and freedom for example, flexible work schedules. However, many firms are starting to realize what our results also indicate: a *“tight correlation between personal interactions, performance and innovation”* and are

implementing changes accordingly to promote more collectivistic brainstorming of ideas [86]. In other words, giving precedence to firm-level accomplishments rather than individual accomplishments. To reiterate our previous example, Yahoo revoked mobile work privileges and Facebook got rid of individual cubicles in their office building [64]. Overall, the interaction of the institution-based view and the culture-based view helps to understand the technological innovation-performance relationship.

This research also makes some methodological contributions. It introduces the LW procedure over the more conventional [87] approach. The LW approach offers the following advantages (a) empirical findings can be aggregated across studies that do not need correction for measurement error, (b) potential moderation effects can be evaluated, and (c) different types of effect sizes can be included potentially enriching results.

Nevertheless, the paper suffers from several limitations. First, there is still considerable variability that is unaccounted for. Future research can benefit from further exploration of the underlying mechanisms to account for some of that variability. Specifically, in terms of the institutional context of credit availability, contradictory results were found. Further research is needed to get a more nuanced view of additional variables, tightness [62], for example, might be influencing the relationship between credit availability and innovation-related firm performance.

In terms of methodological limitations, the study sample is not exhaustive, and all included studies were published in the public domain. Future research can extend the study sample to include more studies and different types like working/unpublished work (thesis, articles), and books (if available) etc. Scholars can also utilize alternative framework and moderators to enrich our understanding of the relationship. Further, it should be noted that MA studies do suffer from selection bias because outcomes with negative or null findings mostly go unreported and hence

are difficult to find [66]. Finally, given that enough studies are available, the technological-innovation construct can be further segregated into product and process innovation, and a MA can be done on each separately.

Figure 1. Proposed Technological Innovation and Firm Performance Model

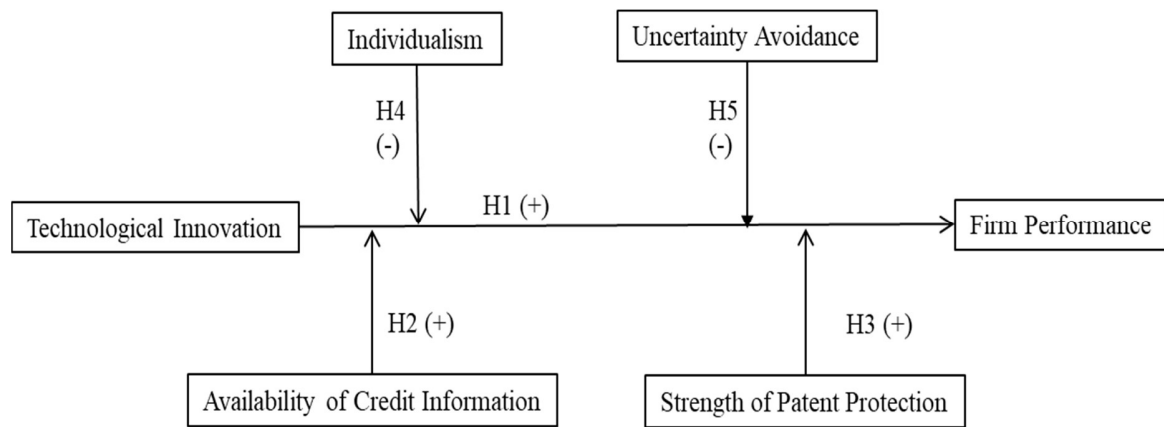


Table I. Descriptive Statistics of the Study Sample (N = 28)

Methodological Characteristics	Number of Studies
Data from Manufacturing Sector	14
Data from Service Sector	4
Data from Both Sectors	10
Cross-Sectional Design	26
Panel Design	2
Controlled for Firm Size	18
Controlled for Industry Effects	11
Technological Innovation Operationalization	Number of Studies ^a
Subjective Measures	16
Objective Measures	17

Note. ^a Some researchers have used more than one type of measure in their study. Hence, the total number of studies adds up to a number greater than the study sample of 28 papers.

Table II. Description of the Moderating Variables

Moderators	Description
Credit Information Index (CII)	CII measures rules affecting the scope, accessibility, and quality of credit information available through either public or private credit registries. The index ranges from 0 to 6, with higher values indicating the availability of more credit information. CII scores were obtained from World Bank's Doing Business database- http://www.doingbusiness.org .
Patent Protection Index (PPI)	PPI measures the strength of patent protection in a nation. It is an unweighted sum of scores along five dimensions: (1) extent of coverage of inventions that are considered patentable, (2) membership in international patent treaties, (3) duration of protection, (4) enforcement mechanisms, and (5) restrictions on patent rights. The index ranges from 0 to 5, with higher values indicating stronger protection. PPI scores were obtained from Ginarte and Park (1997) and Park (2008).
Individualism (IDV)	IDV measures the degree of individualism of a nation. IDV dimension scores were obtained from http://geert-hofstede.com/
Uncertainty Avoidance (UAI)	UAI measures the degree of discomfort with uncertainty and ambiguity. UAI dimension scores were obtained from http://geert-hofstede.com/
Methodological Variables	Description
Manufacturing Industry Data	Dummy variable coded as 1 if study examined only manufacturing industries.
Firm Size	Dummy variable coded as 1 if study controlled for firm size.
Industry Effects	Dummy variable coded as 1 if study controlled for industry effects.

Table III. Results of HOMA (Hypothesis 1)

Focal Relationship	N	k	Mean ρ	S.E.	Q test	I ²
Technological Innovation to Firm Performance	102,519	132	0.099****	0.016	2985.1***	95%

Note. N= total sample size; k= no. of effect sizes; mean ρ =estimate of population correlation; S.E.= standard error of mean ρ ; Q= Cochran's homogeneity test statistic; I²= scale-free index of heterogeneity; * p-value<0.1, ** p-value<0.05, *** p-value<0.01, **** p-value<0.001

Table IV. Results of MARA (Hypothesis 2-5)

Variables	Model 1		Model 2	
	Coefficient ^a	S.E.	Coefficient ^a	S.E.
Constant	.037	0.089	0.161	0.099
<i>Methodological Variables</i>				
Manufacturing Industry Data	0.036	0.037	0.036	0.041
Service Industry Data	0.126**	0.058	0.036	0.065
Study Design	0.07	0.078	-0.058	0.085
Firm Size	-0.027	0.039	-0.011	0.040
Industry Effects	-0.023	0.034	-0.024	0.039
<i>Moderators</i>				
Credit Information Index (CII)			-0.006	0.017
Patent Protection Index (PPI)			-0.039*	0.020
Individualism (IDV)			-0.064****	0.019
Uncertainty Avoidance (UAI)			-0.033*	0.017
R ²	0.05		0.14	
k	132		132	
Q _{model}	10.75**		29.32****	
Q _{residual}	193.66****		174.31***	

Note. ^a Unstandardized regression coefficients; k= no. of effect sizes; Q= Cochran's homogeneity test statistic;
* p-value<0.1, ** p-value<0.05, *** p-value<0.01, **** p-value<0.001

Table V. Robustness Test

Technological Innovation Operationalization	N	k	Mean ρ	S.E.	Q test	I ²
Subjective Measures	16,508	46	0.195****	0.008	628.77***	93%
Objective Measures	86,011	86	0.056****	0.018	2337.85***	96%

Note. N= total sample size; k= no. of effect sizes; mean ρ =estimate of population correlation; S.E.= standard error of mean ρ ; Q= Cochran's homogeneity test statistic; I²= scale-free index of heterogeneity; * p-value<0.1, ** p-value<0.05, *** p-value<0.01, **** p-value<0.001

APPENDIX A

List of Studies in the Sample

No.	Author/s	Journal	Year	Country
1	Berchicci [88]	Research Policy	(2013)	Italy (IT)
2	Han et al. [28]	POM	(2013)	US
3	Zhang et al. [7]	POM	(2012)	US
4	McDermott and Prajogo [13]	IJOPM	(2012)	Australia
5	Jean et al. [10]	DS	(2012)	Taiwan
6	Song et al. [12]	JOM	(2011)	US
7	Lee et al. [89]	IJOPM	(2011)	South Korea
8	Choi et al. [90]	Research Policy	(2011)	China
9	Yam et al. [91]	Research Policy	(2011)	Hong Kong
10	Liao and Rice [92]	Research Policy	(2010)	Australia
11	Eddleston [93]	JMS	(2008)	US
12	Durand et al. [29]	SMJ	(2008)	France (FR)
13	Oke [32]	IJOPM	(2007)	UK
14	Heeley et al. [42]	AMJ	(2007)	US
15	Namara & Baden-Fuller [94]	Research Policy	(2007)	US, UK, FR, IT, GR
16	Jansen et al. [14]	MS	(2006)	Europe
17	Ettlie & Pavlou [27]	DS	(2006)	US
18	Thornhill [41]	JBV	(2006)	Canada
19	Mallick & Schroeder [95]	POM	(2005)	US
20	Lantz & Sahut [96]	IJB	(2005)	Europe
21	Qian & Li [97]	SMJ	(2003)	US
22	Li and Atuahene-Gima [11]	SMJ	(2002)	China
23	Li and Atuahene-Gima [98]	AMJ	(2001)	China
24	Yamin et al. [99]	IJPE	(1997)	Australia
25	Feeny & Rogers [100]	AER	(2003)	Australia
26	Leiponen [101]	EINT	(2000)	Finland
27	Terwiesch et al. [37]	JPIM	(1998)	US, Japan, Europe
28	Kelm et al. [102]	AMJ	(1995)	US

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